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Fracture resistance different types of long term provisional fixed dental prostheses (*In-vitro* study)

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Abstract
Objectives: *The aim of this in-vitro study is to evaluation fracture resistance of different types of long term provisional FDPs*
Material & methods: *A total of 24 specimens of provisional FDPs were fabricated from 1 conventional bisacryle provisional material Protemp 4 (group P) and 2 CAD-CAM provisional materials acrylate polymer with filler Vita CAD Temp (group V) and PMMA Telio CAD (group T) and epoxy resin dies were used and divided into 3 groups randomly according to materials. 24 glass ionomer encapsulated were used for cementation 24 FDP on it's the correspondent die. After cementation, all specimens were subjected to 75000 thermo-mechanical cycles (5 °C-55 °C). After that, all specimens were mounted on the universal testing machine were loads directed at central fossa of the occlusal surface of pontic. A mean value of each group was calculated and used in statistical analysis.*
Result: *For the fracture resistance illustrates that there is statistically significant higher mean fracture resistance among groups T then group V and the least is detected for group P (1212.12 N, 681.25 N & 473.14 N respectively). Post Hoc Tukey test was done to detect within group significance and shows that there is statistically significant difference between groups V & T, V & P and T & P.*
Conclusion: *CAD-CAM provisional FDPs showed higher fracture resistance than conventional FDPs after thermo-mechanical cyclic loading. Therefore, provisional CAD-CAM FDPs are suitable for long term uses.*
Keywords: *provisional fracture resistance, fracture load of long term provisional FDP, long term provisional fracture resistance.*

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I. Introduction

In fixed prosthetic treatment, provisional restorations meet the functional and aesthetic expectations of the patient until the final restoration, as well as protect pulpal tissue against physical, chemical and thermal injuries. In addition, they are necessary in ensuring occlusion, contour and health of gingival tissues[1]. Provisional FDPs are used for short-term or long-term[2], aesthetics or phonetics and occlusion, and as a provisional prosthodontic treatment in cancer patients before healing time[3].

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The situations of long term uses are orthodontic treatment, Surgical and periodontal therapy where crown lengthening procedure are needed before final restoration , restoring aesthetics or phonetics and occlusion, and as an provisional prosthodontics treatment in cancer patients before healing time[4].

Bis-acrylic or bis-acrylate composites are distinguishable from methacrylate resins in that it is similar to composite restorative materials since it is composed of bis-acrylic resin and inorganic fillers. There are however some benefits, such as low exothermic setting reactions and lower polymerization shrinkage unlike the methacrylates, and are kinder to the underlying pulpal tissue. In addition, it provides an acceptable marginal adaptation with good transverse strength and resistance to abrasion[5].

Provisional restorations for CAD-CAM systems are available in the form of blocks and blanks for CAD-CAM machining. These materials are made under optimum polymerization conditions with no water interference, providing enough time for post-polymerization processes and relaxation phenomena to occur. This means that provisional restorations made from CAD-CAM blocks, whether monomethacrylate or dimethacrylate, have superior mechanical and physical qualities from the moment they are installed compared to those made using traditional direct procedures.[6].

Long-term provisional FDPs need materials with stable mechanical properties that have enough fracture resistance to withstand the masticatory force[7].

The aim of this in-vitro study is to evaluations fracture resistance of different types of long term provisional fixed dental prostheses.

II. Materials and Methods

Additional polyvinyl siloxane impression material (Ghenesyl, Lascod, Italy) was used to take impression for phantom model (Albanaa, Egypt) with teeth 35, 36 and 37 teeth**.** Vacuum formed plastic sheet (Pvc sheet casting mold, China) was used for fabrication of the external surface form of the conventional provisional FDPs. The phantom model was sprayed with scanning spray (Renfert, Germany) and scanning of the outer surface of teeth 35**,** 36 and 37 using 3D dental scanner (Ceramil map-400, Germany). The resultant STL file was saved to be used for fabrication of the external surface form of the provisional CAD-CAM FDPs**.**

Tooth 36 was removed from the phantom model. The abutments (35 and 37) were prepared according to full ceramic crown tooth preparation protocol. Additional polyvinyl siloxane impression was taken for the prepared teeth on the phantom model and was poured into stone. The model stone was used for fabrication of duplicating silicone mold . The duplicating silicone (Replisil 22 N, Dent-e-con, Germany) was was used for epoxy resin dies (Kemapoxy 151, CMB, Egypt) duplication to fabricate 24 identical epoxy resin dies.
A total of 24 epoxy resin dies were constructed and randomly divided into 3 groups of 8 dies each.

- Group P: Epoxy resin dies recieved Protemp 4 (3M ESPE, Seefeld, Germany), conventional provisional FDPs
- Group V: Epoxy resin dies recieved Vita CAD Temp (Vita Zahnfabrik, Bad Sackingen, Germany /Liechtenstein), CAD-CAM provisonal FDPs
- Group T: Epoxy resin dies recieved Telio CAD (IvoclarVivadent, Schaan, Liechtenstein) CAD-CAM provisonal FDPs

Group P made from Protemp 4 by conventional techqunic, three coats of die spacer [8](Yeti Dental, Germany) were applied on each abutment tooth over the occlusal and axial surfaces with the supplied brush. The mixing tip was attached to allow for auto mixing of the two pastes of Protemp 4, then it was injected in the vacuum formed plastic sheet and filled the whole mold with the material without removing the tip from the material to avoid air trapping **.**The vacuum formed plastic sheet was placed on the die and wrappad with elastic band till the mixed material completely set.

Each epoxy resin die from groups V & T was sprayed with the scanning spray and scanned using the 3D dental scanner and the FDP were designed using exocad software (exocad GmbH, Align Technology, USA). The software was used for subtraction of unprepared and prepared STL, the resultant was a STL file of the new provisional FDP shell with cement space 50 µm thickness with final bridge design. CORiTEC 350i (Imes-icore, Eiterfeld, Germany) machine was used for milling the blank wet milling for Vita CAD Temp and dry milling for Telio CAD according to the manufacturer instructions. Finished and polished was done using the rotary rubber cups to smooth out the attachment points and each FDP was re-examined on its corresponding die. A specially-designed custom-made cementation device was used for cementation the 24 specimens. The encapsulated glass ionomer cement (GC Fuji I Capsule, GC, Tokyo, Japan) was applied in the fitting surface of the 2 retainers and each FDP was seated on its corresponding die and a constant load of 5 Kg[9] was loaded over each specimen.

The thermo-mechanical ageing was carried out with the help of programmable logic controllers and the recently created four-station multimodal ROBOTA chewing simulator (Model Ach-09075dc-T, Ad-Tech Technology Co., Ltd., Germany) integrated with thermo-cyclic protocol operated on servo-motor (Model ACH-09075DC-T, AD-TECH Technology Company, Germany). A weight of 5 kg, comparable to 49 N of chewing force was exerted, and the chewing was simulated vertical and horizontal movements simultaneously in the thermodynamic condition with 5-55 ^{0}C thermocycling. The test was repeated 75000 times to clinically simulate 6 months chewing condition, according to previous study [10] .

Each provisional FDP from each group was individually mounted on a computer-controlled material testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software) **(Figure1) .** Each specimen was fixed into the lower compartment of the testing machine by tightening screws. Fracture test was done by compressive mode of load applied over the pontic occlusally using a metallic rod with spherical tip (5.6 mm diameter) attached to the upper movable compartment of the testing machine traveling at cross-head speed of 1mm/min with tin foil sheet (Aluminum foil, Queen, Egypt) applied in-between the pontic and the spherical tip to establish a uniform stress distribution and minimize the transmission of local force peaks, use this tip. An audible crack indicated the load at failure, which was corroborated by a dramatic drop in the load-deflection curve, which was recorded using computer software (Bluehill Lite Software Instron® Instruments). The amount of force required to fracture was measured in Newtons.

Figure 1: Specimen in the Instron fracture test device

III. Results

For the fracture resistance illustrates that there is statistically significant higher mean fracture resistance among groups T, V and the least is detected for group P (1212.12 N, 681.25 N & 473.14 N respectively). Post Hoc Tukey test was done to detect within group significance and shows that there is statistically significant difference between groups V &T, V & P and T & P, as shown in **Table 1** and **Figure 2.**

Table (1): Comparison of fracture resistance between studied groups.

	Group P	Group V	Group T	test of significance (One Way ANOVA test)
	N=6	N=6	N=6	
Fracture resistance (N)	473.14±83[bc]	681.25±47.23[ab]	1212.12±229.99[ac]	F=42.14 P<0.001*

*Similar superscripted letters denote significant difference between groups with Post Hoc Tukey test, *statistically significant if $p \leq 0.05$*

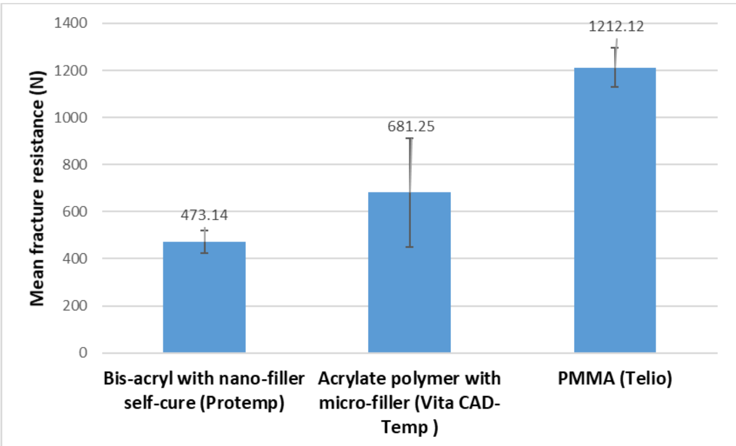

Figure (1): mean fracture resistance among the studied in Newton

IV. Discussion

In fixed prosthetic treatment, provisional restorations meet the functional and aesthetic expectations of the patient until the final restoration, as well as protect pulpal. In addition, they are necessary in ensuring occlusion, contour and health of gingival tissues[1]. Provisional FDPs are used for short-term or long-term[2], therefore, they are necessitate materials with good fracture resistance[11].

In this study, three different types of long term provisional materials were used, which were different in their composition and fabrication techniques. Protemp 4 (group P) is a bisacrylic composite material with nanotechnology-based fillers used as conventional provisional FDP. Vita CAD Temp (group V) is an acrylate polymer with Sio_2 micro-particles as fillers while Telio CAD (group T) is a pure PMMA. CAD-CAM provisional materials have superior mechanical and physical properties than the conventional one.

Phantom model with typodont teeth (35, 36, &37) was used to standardize the preparation and the external surface form of restoration for all specimens.

Impression was taken for teeth 34, 35 and 36 and poured into extra hard stone model to fabricate a vacuum formed plastic sheet which represents the external surface form for the conventional provisional FDPs as phantom model can not withstand the high temperature of vacuumed device. While phantom model with typodont teeth was scanned to obtain an STL file for the external surface form of teeth before preparation to be used for construction of the CAD-CAM provisional FDP.

Tooth #36 was removed from the phantom model and the socket was filled with pink wax to simulate the edentulous area. The abutment teeth (35 & 37) were prepared on the phantom model. Impression was taken for prepared teeth and edentulous span and poured into stone to fabricate a duplicating silicon mold, which was used to gain 24 identical resin dies. Resin dies were used in this study instead of natural teeth to avoid morphology variation, cracks or inconsistent tooth structure that might lead to tooth fracture on different loads during testing. Also standardizing human teeth is not easy and is affected by different factors (ages, storage media, time of extraction and morphology variation) as a result these factors can affect the modulus of elasticity of the each tooth[12]. Moreover, epoxy resin die has an elastic modulus similar to human tooth achieve results that are closer to clinical conditions[13] .

Three coats of die spacer were applied on the abutments of the conventional provisional FDPs to gain thickness of approximately 50 μm, to simulate the set die spacer for the CAD-CAM groups (50 μm).

Single type of finishing and polishing kit was used to finish and polish the 24 FDPs to standardize the surface texture.

A specially-designed custom-made cementation device represented the antagonist of the occlusal surface of the FDP was used for cementation to apply uniform constant load on each abutment during cementation.

In this study, glass ionomer cement was used for cementation of the provisional FDPs to achieve good retention for long term period. Moreover, permanent cementation avoids possible premature loosening of FDPs during thermo-mechanical cyclic loading which might occur when using provisional cement, as mentioned by previous study[14].

A previous study showed that the chewing force of molars varied between 20 and 120 N[15]. Therefore, a 50 N occlusal load was applied using the chewing simulated vertical and horizontal movements simultaneously in the thermodynamic condition 75000 with 5C-55^0 C cyclic to clinically simulate 6 months chewing condition. The samples were continuously in contact with the antagonist with occlusal and lateral forces.

A piece of foil was placed between the FDP specimen and the loading ball to act as stress breaker simulating the cushion activity of food between upper and lower teeth and help in avoid cone cracks[16].

In this study the fracture resistance of provisional FDPs after 75000 thermo-mechanical cyclic loading are high in CAD-CAM groups V& T while less in conventional group P.

For Teilo CAD (group T), fracture resistance was the highest (1212.12±229.99) may be due to homogeneity of the material which composed of pure PMMA, therefore distribution of the applied load and more resilience.

For Vita CAD Temp (group V), fracture resistance was less than group T (681.25±47.23) may be due to heterogeneous composition and presence of filler particles which composed of acrylate polymer with filler, therefore the filler particles act as stress concentrating area decreased the fracture resistance of the material.

For Protemp 4 (group P), fracture resistance was the less than the CAD-CAM provisional materials (473.14±83) may be due to heterogeneous composition which composed of bisacryle composite matrix with filler. The filler particles act as stress concentrating area. Moreover the resin matrix less strength than the acrylate polymer therefore, decreased the fracture resistance of the material.

CAD-CAM blocks exhibit high quality concerning its mechanical characteristics and microstructure for the fact that they were industrially fabricated under constant high pressure and heat (polymerization taken place during these fabrication steps only). This permits prosthesis to be fabricated with high fracture resistance when compared with conventional fabricated materials[17].

The result of this study agreed with those of **Jasim et al.,** [6] although they evaluated the fracture resistance without thermo-mechanical cyclic loading and used metal dies.

While, the result of this study partially disagreed with those of **Edelhoff et al.,** [15] who found that Telio CAD showed high fracture resistance followed by Protemp 4 and the least fracture resistance was Vita CAD Temp, may be due to use of metal dies and 240000 thermo-mechanical cyclic loading.

V. Conclusion

CAD-CAM provisional FDPs showed higher fracture resistance than conventional FDPs after thermo-mechanical cyclic loading. Therefore, provisional CAD-CAM FDPs are suitable for long term uses.

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